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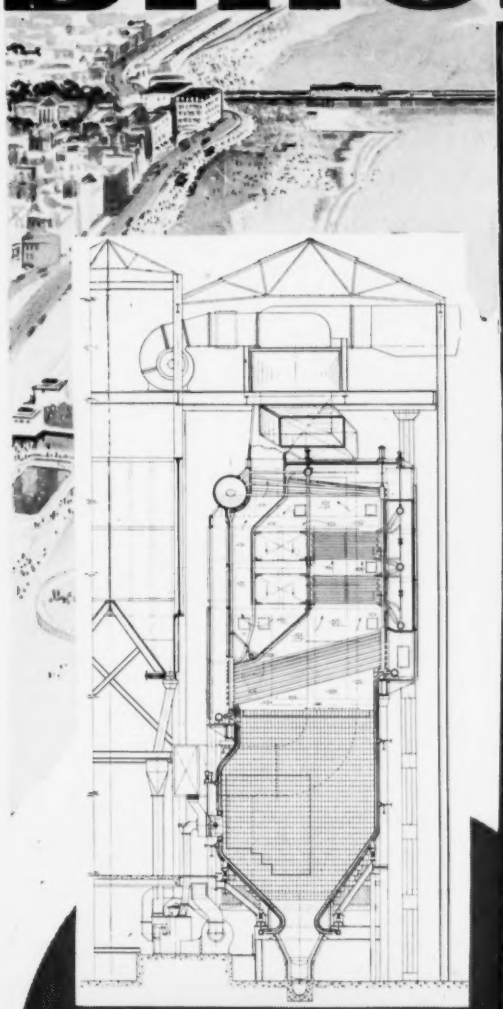

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NAME	No. of Boilers	Pressure—Lbs. sq. in.	Capacity—Lbs. hr./blr.
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Brighton	2	675	175,000
Broken Hill	1	200	60,000
Beresnikovsky	4	853	330,000
Betteshanger	2	200	55,000
Belqas	3	440	46,800
Barton	1	375	130,000
Catania	1	370	110,000
Callenders Cables	4	275	20,000
Chosen Denryoku	4	455	132,000
Dunston	2	625	156,000
Dutch States Mines	2	500	220,000
Figols	2	355	77,000
Ford Motor	2	200	40,250
Ford Motor	3	1,250	205,000
Gravenhage	2	298	77,000
Gravenhage	2	384	220,000
Hokkaido Dento	1	455	143,000
Hayle	1	250	62,500
Horden Collieries	3	200	60,000
I.C.I.	1	200	50,000
I.C.I.	1	575	77,000
I.C.I.	2	625	150,000
I.G.R. Japan	4	384	132,000
Ironbridge	3	400	270,000
Kumamoto Denki	6	580	233,000
Kansai	4	600	319,000
Korean Corn Products	2	400	54,000
Kyushiu	2	550	280,000
Kashira	5	426	423,200
Londonderry Collieries	2	200	36,000
Langreo	4	200	36,000
Liverpool	3	300	125,000
Mount Isa Mines	3	270	62,500
Mitsui Dyestuff	2	745	186,000
Mitsui Mining	2	385	80,500
Nippon Seitetsu	2	426	153,000
Nippon Seitetsu	2	429	126,500
Nippon Rayon	3	425	132,000
Norsk Hydro	3	540	60,000
North Met.	2	200	90,000
Powell Duffryn	3	150	50,000
Powell Duffryn	1	160	30,000
Poznanski	1	340	75,000
Roan Antelope	4	275	67,500
Rosario	2	356	66,000
Rotterdam	1	199	57,200
Rotterdam	3	427	220,460
Seisen Godo	2	225	50,000
Saka Power	3	489	168,000
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York Street Flax	1	280	50,000
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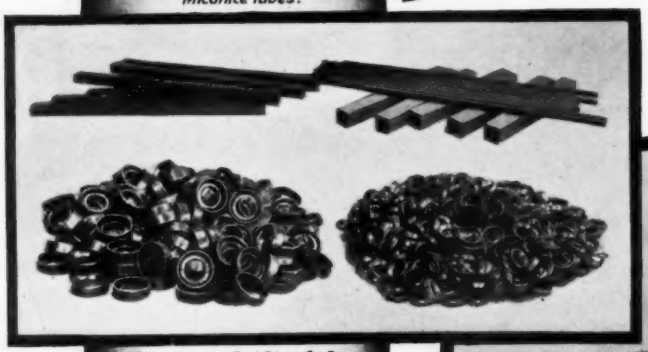

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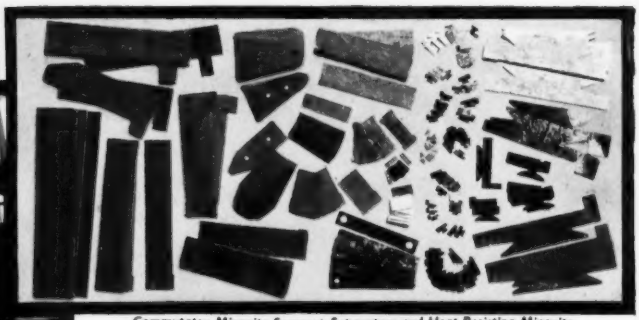

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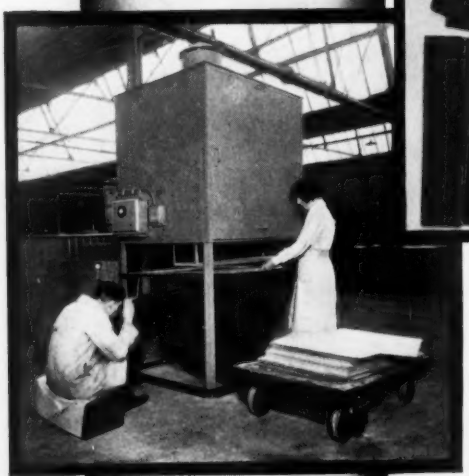

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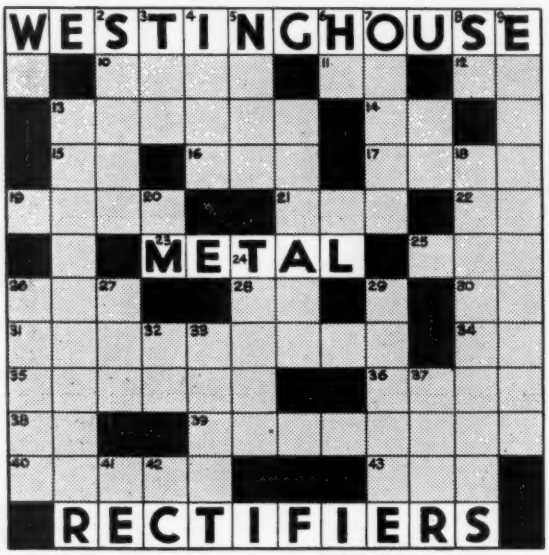

ACROSS.

10. Era.
11. Out of.
12. Preposition.
13. Metal.
14. Preposition.
15. Unit.
16. Anger.
17. Half.
19. Cleanse.
21. Shelter.
22. Type of mains Supply.
25. Prefix meaning singular.
26. Since.
28. Preposition.
30. You.
31. Lasting.
34. Gained, but lost nothing.
35. Healthy.
36. Method of Calculation.
38. Half wicked.
39. Safety.
40. Wait on.
43. Doctor an Animal.

DOWN.

1. Us.
2. Retards.
3. Hint.
4. Zulu Regiment.
5. Poet's never.
6. Pronoun.
7. Chemical.
8. Thus.
9. Effective force.
13. Alter.
18. Much power (two words).
20. Royal.
24. Parisian Aunt.
26. Afterwards in France.
27. Royal emblem.
29. Go without food.
32. Some are variable.
33. Advantage.
37. Ultimate transport.
41. Concerning.
42. Military honour.

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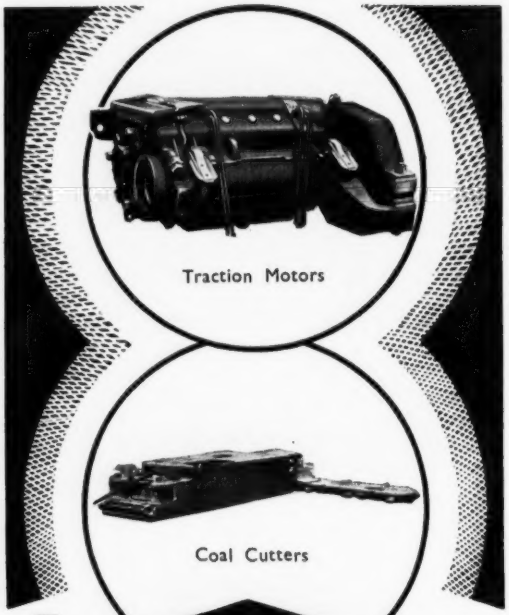

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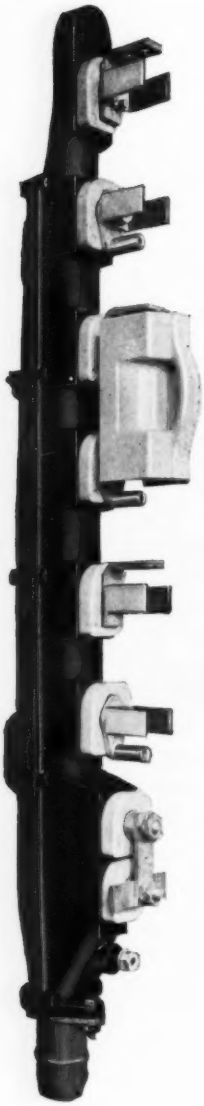

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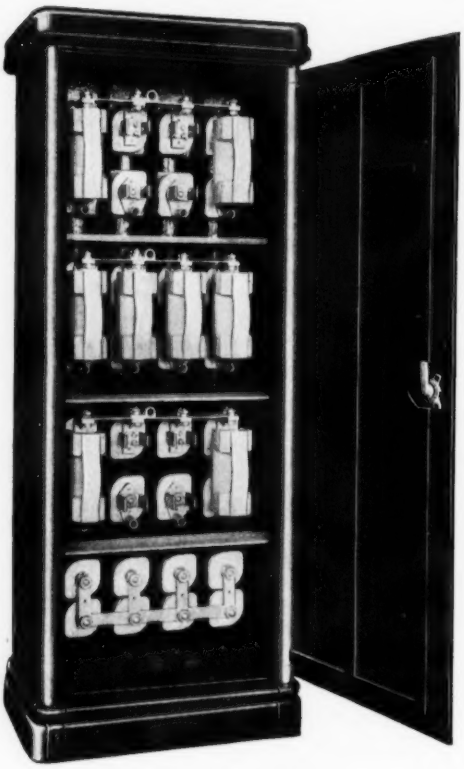
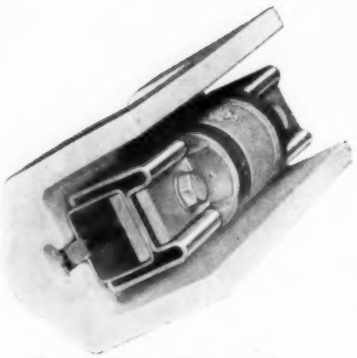


4-way, 3-phase, 4-wire Pillar.



Porcelain Handle with Cartridge fuse.

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(Patent Nos. 189,684 and 429,806)

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Tongland Power Station, looking towards Tail Race

The English Electric Journal

Vol. VIII. No. 2 MAY, 1936 One Shilling.

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All Communications respecting Editorial Contents should be addressed to The Editor, The English Electric Journal, The English Electric Company Limited, Stafford.

EDITORIAL.

The first article in this issue continues the description of the Galloway Water Power Company's hydro-electric scheme which was commenced in the previous issue (Vol. VIII, No. 1); in this instalment the water turbines and alternators at the Tongland Power Station are described.

It is of interest to record that the Company has (within the last 15 years) manufactured three quarters of a million H.P. of water turbines and approximately the same number of kVA. of water wheel generators. These are operating in all parts of the world and constitute some of the foremost hydro-electric installations.

The second article entitled "Protection of Motors" by Messrs. L. Roberts and R. D. Ball draws attention to the fact that present-day methods of safeguarding motors, whilst providing satisfactorily against failure to start, stalled condition and continuous heavy overloads, do not protect the motor against such contingencies as blockage of ventilation ducts, frequently repeated overloads, and high ambient air temperature. All such causes of failure of the motor are linked with the actual temperature of the motor windings and protection against them requires a temperature actuated device fitted on the motor itself. The Authors after carrying out considerable experiments developed

the "English Electric" Burn-out Protector and their article describes the applications and function of this device.

The third article describes and illustrates Electrical Precipitation plants recently installed by the Company. The illustrations show in detail the arrangement of the high-tension direct current sets and switchgear under varying conditions of power supply and layout to give the maximum flexibility of operation of the precipitation plant. Attention is drawn to an interesting equipment in which the high-tension generators are driven by a small high-speed steam engine.

The last article describes and illustrates the new Steam Generating plant which the Company has just installed at the Rugby Works; this plant will enable steam turbines to be tested up to a pressure of 485 lbs./sq. in., and with steam at a total temperature of 850° F., it will be possible to test turbines up to loads of approximately 4,000 kW. at this pressure and temperature.

Two 55,000 kVA. Banks of Transformers, 76,000/42,000 volts, 3-phase, 50 cycles; each bank comprising three single-phase 18,333 kVA. units, for the Victoria Falls and Transvaal Power Company, Ltd., South Africa.

The Galloway Water Power Scheme.

By H. L. BAZALGETTE, A.C.G.I., A.M.I.C.E.

(*Continued from Page 12, Vol. VIII, No. 1.*)

Hydraulic Equipment at Tongland.

Tongland Power Station is equipped with three main vertical shaft reaction water turbines and one auxiliary horizontal shaft reaction water turbine, directly coupled to their generators, as shown in plan and elevation in Figs. 2 and 3, published in the last issue of this Journal.

The main units are designed for a maximum continuous load of 17,500 h.p. under a net head of 106 ft., and at maximum output the quantity of water passing through each turbine is 46 tons per second. The speed is 214 r.p.m.

Draught Tubes.

In considering the design and construction of the units, and referring to the cross-section shown in Fig. 4 in the previous issue, it will be convenient to commence the description from the draught tubes and proceed upwards.

The draught tubes are fabricated from mild steel plates by electro-welding and consist of an upper taper pipe and an outflow bend ; the latter portion is provided with a streamlined dividing wall built up of steel plates and beams, the purpose of which is to direct the water flow at this point and thus reduce the eddies and secure the maximum recovery of the velocity head. The draught tubes were sent to the site in sections and were there set in position on low piers and the sections then finally welded together.

Fig. 7 shows the three Tongland draught tubes in process of erection, the middle tube being ready for concreting, and in the foreground can be seen the wood forms and reinforcement rods for the discharge exit.

The concrete, which is strongly reinforced throughout in order to secure a solid foundation, was thoroughly packed around and under the tubes, and as an additional precaution, holes were drilled in the metal and liquid grout forced through them to fill in any voids. After grouting in this way the holes were plugged and the inner surface ground smooth.

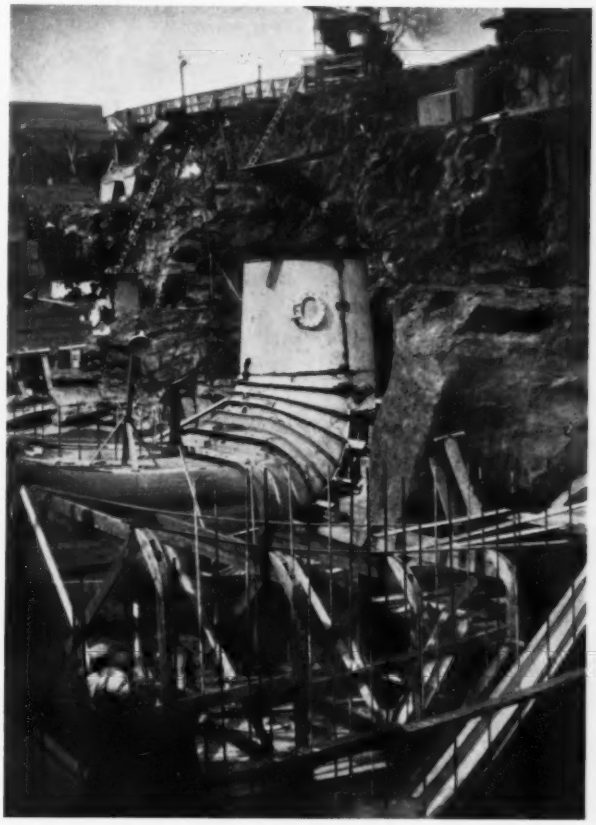

Fig. 7.—Tongland Draught Tubes in course of erection.

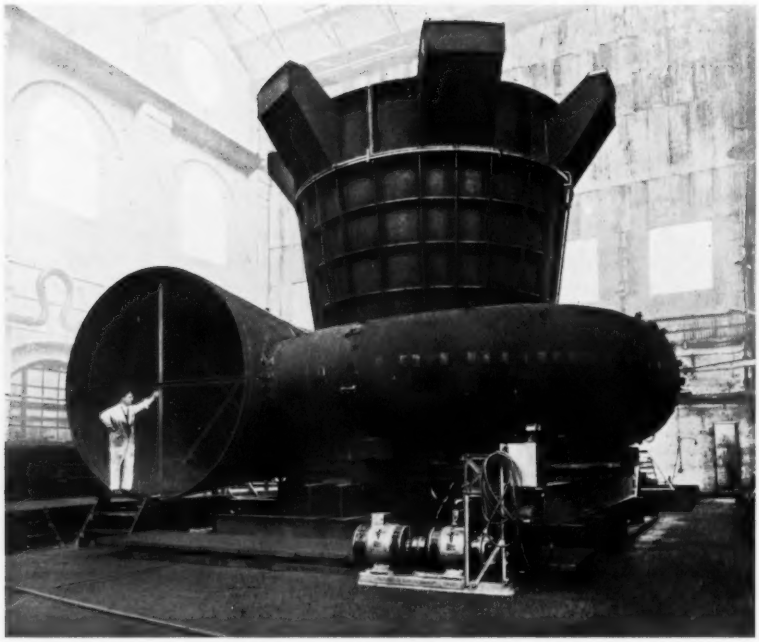

Fig. 8.—Spiral Casing and Generator Support Assembly.

SPIRAL CASING AND GENERATOR SUPPORT.

The turbine spiral casings are connected directly to the pipelines without any intermediate stop valves and consist of mild steel plates rolled to the correct shape to create the intake vortex. The casings have an inlet diameter of 11 ft. 6 in., and are substantially circular in cross-section and of a logarithmic spiral form, which ensures a smooth flow, minimises friction losses, and gives almost complete immunity from erosion.

The spiral casing plates are butt welded to a central cast steel speed ring, having heavy streamlined stay vanes, which form a strong bridge between the upper and lower parts and guide the water into the gate apparatus.

For purposes of transport the casing and speed ring were split into four parts and final assembly and welding carried out on site. Bolted to the turbine speed ring and transmitting the generator load to the foundations is the generator supporting barrel, which is fabricated from mild steel and ensures the maximum rigidity of the whole structure.

The top flange of this support is designed as the alternator bedplate, an intermediate flange of massive construction carries the thrust bearing bracket, and the bottom flange is bolted to the turbine speed ring.

Fig. 8 shows one of the Tongland spiral casings with generator support assembled at the Company's Rugby Works. The Tongland turbines are by far the largest in Great Britain, and the photograph conveys some idea of the size of the main structure.

The angle iron frame against which the man is leaning was only temporary and gave rigidity during erection and transport.

It is interesting to note that the whole of this structure is fabricated by welding, the joints on the spiral casing being simple butt welds to ensure a smooth inside surface, and the longitudinal joints are also butt welds, which are, in addition, reinforced by gussets; these have proved very satisfactory. This vitally important main structure illustrates, probably more than any other feature, the great advantage of

the joint design and manufacture by the same Company in its own works of both turbines and generators.

The Company is the only British firm to undertake the manufacture of both water turbines and generators, and is thus able to secure the closest co-operation between the hydraulic and the electrical design staffs, ensuring a thoroughly satisfactory combined unit.

Fig. 9 shows two of the Tongland spiral casings in position on their foundations prior to hydraulic pressure testing and concreting.

The cylindrical test-cover to close the inner part of the casing is being lowered into position in the foreground of the photograph, and in the background can be seen the top part of the draught tube taper piece protruding through the concrete ready to receive No. 3 casing.

Fig. 9.—Spiral Casings on Foundations.

Fig. 10.—Tongland Turbine Runner.

The inlet to the spiral casing was closed by a circular test-cover, 11 ft. 6 in. in diameter, and a pressure of 90 lb. per square inch was applied to each casing, all of which successfully withstood the test, a meritorious achievement considering their size and complicated shape.

After pressure testing the casings were completely embedded in concrete, it being the Company's standard practice to bury the casings of large vertical turbines in the foundations, as this ensures absolute solidity and freedom from vibration. All the vital parts of the turbines can be dismantled without disturbing the spiral casing, the life of which is practically unlimited on account of its streamline design and the high safety factor.

Runner.

The runner is illustrated in Fig. 10, and it consists of a one-piece steel casting, for which the necessary core box and pattern were made at Rugby Works and supplied to the steel founders.

A dummy section of the runner was first made at the works in cast iron in order to check the accuracy of the core box.

The vanes are carefully designed to ensure long life in continuous operation, and the inlet and outlet edges are streamlined. The wheels are protected by shrunk-on interchangeable steel rings and are provided with balancing holes for the water ; the torque is transmitted to the shaft by a laid-in transversal key, thus the coupling bolts are a clearance fit, no reamering is necessary, and the stresses are fully determinate.

The casting was received in a rough machined condition from the steel founders with all the water passages in a rough state, and it was necessary completely to grind and finish these smooth before despatch. This, as may be seen from the photograph, is no mean task, but the finish of the vanes is of great importance in order to secure a high efficiency. The runners were carefully balanced before leaving the works.

Fig. 11 shows a complete runner and shaft being lowered into position on site.

Regulating Mechanism.

The water passes to the runner through a regulating mechanism consisting primarily of twenty-four steel swivel-gates cast integral with their stems, which rotate in gunmetal bushes ; these are lubricated from the top by means of a grease gun ; large collars at the junction of the vane body with the stems protect the latter against wear and water leakage is prevented by means of rubber packing rings. The lower stem bearings are completely closed, this being the simplest and safest design for this location.

The swivel-gates are operated by a regulating ring, fabricated from mild steel, to which they are connected by levers and links of the " offset " type, which are designed to reduce to a minimum the power required from the governor.

The connecting links are made of cast iron and are so designed that, in the event of an obstruction, such as wood or other debris, becoming lodged in them, they will break a considerable time before an excessive force is exerted on any part of the guide apparatus ; in order to fix the exact breaking load a cut is made in the link, the correct depth of this cut being obtained from tests on similar links at the Works.

The regulating ring is supported by the main turbine cover and slides on well-lubricated bronze pads, thus reducing friction by allowing the ring to centre itself so as to balance the forces exerted on it by the two connecting rods to the governor servomotor which provides the power for the operation of the gates.

Turbine Top Cover Assembly.

The turbine top cover is shown in Fig. 12 partly assembled at the Works, and in this photograph the regulating ring and the pins for operating the swivel-gates can also be seen. The whole cover is of fabricated construction throughout and is rigidly bolted down to the speed ring ; it carries the turbine bearing housing, which is dowelled in position in order to obtain correct alignment.

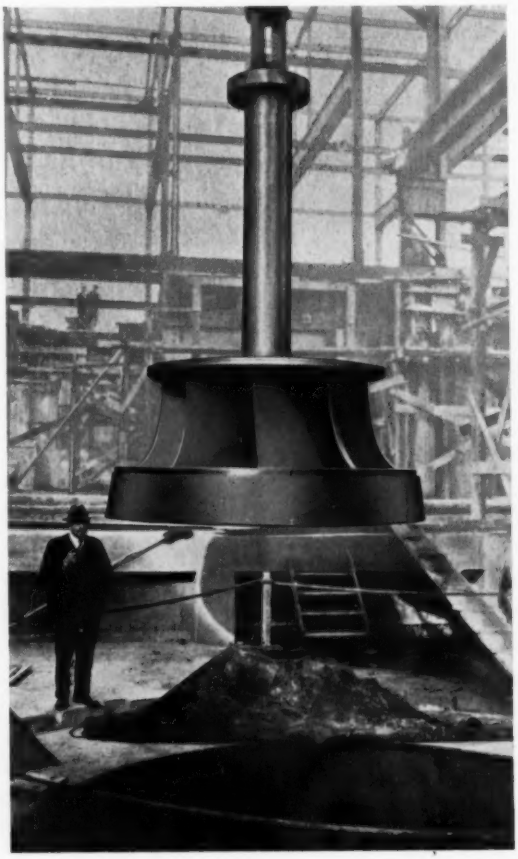

Fig. 11.—Tongland Turbine Runner being lowered into position.

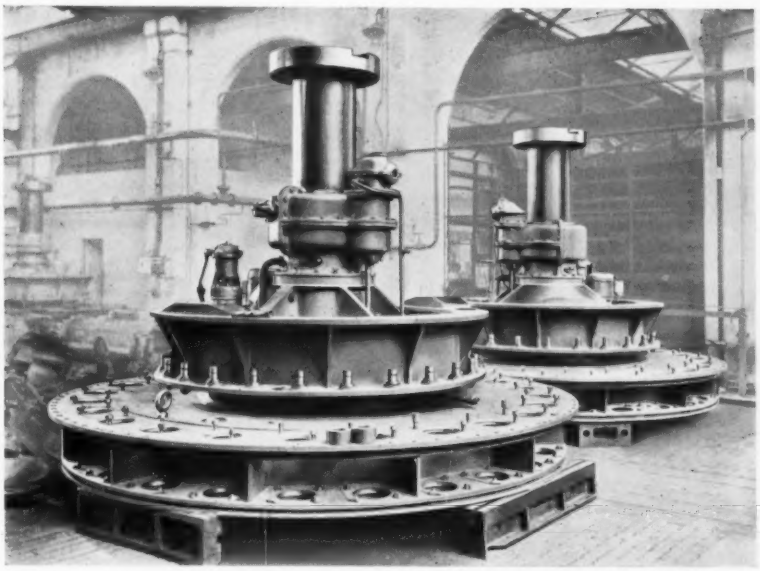

Fig. 12.—Turbine Top Cover Assembly.

The bearing bush is lined with special anti-friction white metal, and is provided with spiral grooves for ample oil lubrication, which is effected by a rotary pump, gear-driven from the main shaft. The pump-shaft is extended and actuates, through bevel gears, the horizontal shaft which drives the governor actuator. The arrangement can readily be followed by studying Fig. 12 and the cross-section in Fig. 4. (Vol. VIII, No. 1.)

The middle of the turbine cover is occupied by the shaft gland, and the space around this gland is used as an oil sump into which the lubricating pump suction pipe extends.

The lubricating oil is fed by the pump through coolers, which are in duplicate so that there is always a stand-by. The bearing is complete with the usual accessories, including overflow, oil return, oil level indicator, safety valve on the oil circuit, and a temperature indicator.

In addition to the gear-driven lubricating pump further protection and stand-by is secured by the provision of a separate electric motor-driven oil pump, which is normally used to flood the bearing before starting up, and also comes automatically into service in the event of the gear-driven pump failing to maintain the oil pressure.

Thus, as soon as water is admitted to the spiral casing and the pressure builds up so that the turbine is ready to run, the motor-driven lubricating pump is automatically started up by means of a contactor switch operated by a contact-type water pressure gauge; when the set starts to run the gear-driven pump comes into operation, and when the oil pressure reaches a predetermined value the motor-driven pump is shut down by means of a lubricating oil contact pressure gauge. On failure of the oil pressure delivered by the gear-driven pump the procedure is reversed and the motor-driven pump is started up.

Another item which can be seen in Fig. 12 is the air snifting valve, the function of which is to admit air to the draught tube when the turbine gates are closing in order to avoid excessive vacuum or shock due to the rupture of the water column when load is suddenly dropped. The air is admitted through this valve to the top of the runner, where it passes to the draught tube through the balancing holes provided in the runner crown.

In accordance with standard practice in hydro-electric work, the rotating parts of both turbine and generator are designed with an ample factor

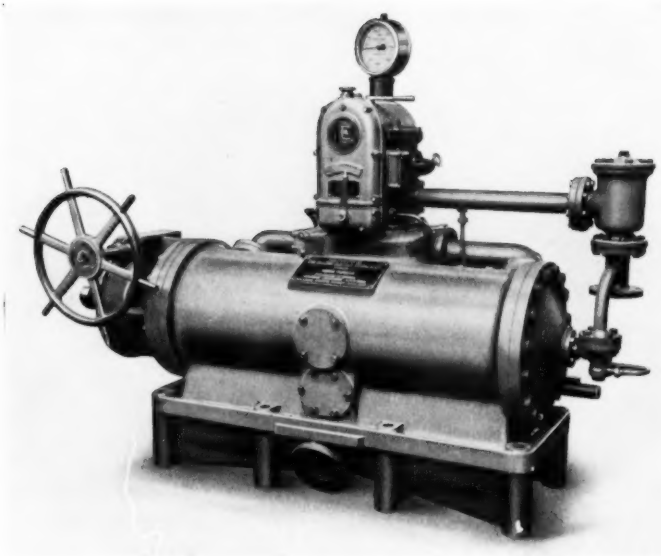

Fig. 13.—Governor Actuator and Servomotor.

of safety to withstand the maximum runaway speed of the turbine, which, in the case of the Tongland turbines, is 95 per cent. above the normal speed.

Arrangements are, however, made to prevent runaway and an overspeed device of the pendulum type is provided on the turbine shaft, which is set to operate when the speed reaches 32 per cent. above normal, and at this speed causes the turbine gates to close by admitting oil under pressure to the closing side of the governor servomotor. At the same time it makes an electrical circuit and causes the main valve at the top of the pipe-line to close.

Oil-pressure Governing System.

As already stated, the turbine gates are opened and closed by a regulating ring, which, in turn, is operated by powerful regulating shafts connected to an oil servomotor; the latter, which is made of cast iron, is shown in Fig. 13, and has a stroke of 14 ins. and a bore of 19 ins. It is capable of exerting an energy of 65,000 ft. lbs.

The servomotor cylinder contains a cast iron double-acting piston, and is provided with a steel crank and handgear and clutch for manual control of the turbine gates when desired. A feature of the whole regulating gear is that there is no necessity for key connections of any description, and the gear is therefore free from lag.

The servomotor receives its pressure oil from an oil pumping set which consists of a rotary pump, with accurately cut steel gears running in gunmetal bushes, driven by a 22 h.p. electric motor; the pump is capable of giving continuously a pressure of 220 lbs. per square inch, which is the normal operating pressure. Located beside the oil pumping set is an oil-pressure receiver, the function of which is to act as a pressure reservoir and to maintain the oil pressure at its correct value. The pump is so arranged that air can be passed through it and made to load the receiver with the necessary air cushion and in addition, a separate air compressor is installed in the power house, which provides a further means for maintaining the pressure in the receiver.

A non-return valve is fitted in the feeder pipe from pump to receiver and an idler valve is branched on to the same pipe. Thus, when the pressure in the receiver reaches 220 lbs. per square inch, the idler valve operates automatically and by-passes the oil from the pump into the oil sump. When the pressure drops below 220 lbs. the idler valve closes and the pump again delivers oil into the pressure receiver. Thus the system is automatic and the pump is only loaded for such time as is necessary to bring the pressure up to normal. The pumping set is fitted with safety valve, oil level gauge and oil level float indicator.

The three oil-pumping sets for the three main turbines at Tongland are interconnected and are also interconnected with the three oil-pressure servomotors; the capacity of the pumps is sufficient to enable two pumping sets to operate three machines and a spare pumping set is therefore always available.

Cooling of the oil is effected by means of water circulating through a coil located inside the oil sump. A contact oil-pressure gauge is fitted on the oil-pressure receiver, and this is so adjusted that when the oil pressure reaches an abnormally low value an audible alarm is sounded on a Klaxon horn and a red lamp lights up on the indicator panel of the set which has given the alarm.

Turning now to the governor actuator, which performs the most important duty of controlling the turbine speed, it has already been mentioned that this piece of apparatus is driven from the turbine by means of bevel gears and a horizontal shaft carried in journal bearings. This shaft drives a pendulum within the actuator by means of a flexible steel strip, the object of which is to avoid transmission to the sensitive pendulum of the vibrations which unavoidably result from a gear transmission and also to make the whole equipment self-aligning.

The actuator pendulum, which contains no trunnions or knife edges and is of great sensitiveness, operates a distributing valve through a quadrant and thus controls the pressure oil to the servomotor, which, as already described, operates the turbine gate mechanism.

Temporary speed variation, due to sudden changes in load, and permanent speed variation, due to the difference in speed at no load and full load, are provided for by a return motion gear, which is so arranged that the compensation can readily be applied to any particular machine and thus secure steady and smooth operation at all loads.

The permanent speed variation is adjustable between 0 per cent. and 4 per cent.

For paralleling the normal speed of the set can be varied by hand or by remote control within a range of 10 per cent.; the remote control is effected by a small reversible electric motor, rated at 1/20 h.p., which is operated from the switchboard.

Incorporated in the governor mechanism is a safety device which closes the turbine gates in the event of the speed of the set dropping by 30 per cent. below normal, and this device also protects the set in case of governor drive failure. A servomotor by-pass is also fitted, and this has to be opened when the handgear of the servomotor is brought into operation.

This handgear, which can be seen in Fig. 13, is mounted at the end of the servomotor cylinder, and consists of a handwheel which drives the piston rod by means of a worm, the drive being so arranged that the handgear can be clutched in and out at any position of the servomotor.

By means of this gear the freedom of the governor gear and the satisfactory operation of the gate apparatus may be tested.

In actual service, operation is entirely by oil pressure and the handgear is only used as a locking device when the set is shut down.

The governing system briefly described above is the normal arrangement provided by this Company and is working satisfactorily in all parts of the world. The actuator design is standardised for all sizes and types of turbines, and is particularly neat and compact, as will be appreciated from Fig. 13, where it is shown mounted in its normal position above the servomotor. Backlash and friction have been eliminated by making all contacts bear continuously in the same direction as well as by avoiding the use of levers and pins, and the whole forms a very compact, dustproof and highly sensitive series produced mechanism.

Diffusing Discharge Regulator.

As mentioned at the end of the last article, the Company's contract included the provision of a discharge regulator or disperser for diffusing the discharge from the surge tower, so as to destroy its energy without endangering the power house building or the river bed.

The disperser is fabricated from steel plate by electro-welding, and consists of a carefully shaped and reinforced mouthpiece ring, having an inlet diameter of 11 ft. 6 in., tied by strong ribs to a streamline inner cone, which discharges the water in the form of a hollow cone and destroys its energy by air friction and eddies. In order to facilitate transport the disperser, which at its largest diameter measures 13 ft. 6 in., was split into two halves, these being welded together at site. The mouthpiece was welded to the pipeline leading from the surge tower overflow, and the

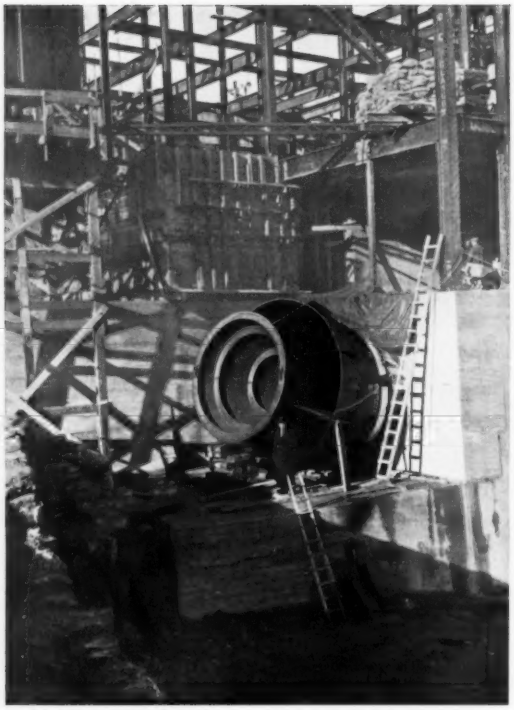

Fig. 14.—Tongland Disperser.

regulator was securely embedded in the power house foundations. The disperser was tilted slightly upwards and inclined away from the river bank, and this ensured that the discharge is kept clear of the wall of the building and falls mainly on the water cushion provided by the tailrace.

Thus deep excavation near the river bank was rendered unnecessary, and it was also possible to dispense with a concrete apron, which is often required in front of such discharge regulators. An important feature of the disperser is that, in spite of its upward tilt, the lower part of the mouth is level with the bottom of the pipeline, so that water cannot accumulate in the latter, but will immediately be discharged outwards. The discharge capacity is 4,000 cusecs and, since the head is low, this quantity of water can be discharged over a comparatively small area.

It is interesting to note that the shape and streamlining are the same as for the Company's standard cylindrical balanced diffusing discharge regulators. Fig. 14 shows the disperser in process of erection.

Generators.

The design and construction of the generators may now be considered and the cross-section shown in Fig. 4 of the first article (Vol. VIII, No. 1) should be referred to again.

The Tongland generators are of outstanding interest inasmuch as they are the first machines of the umbrella type to be designed and built in this country, although the type has for some years been popular in Canada and the United States. For low and medium head plants where the combination of slow speed and flywheel effect are favourable, the umbrella construction for vertical shaft machines has considerable advantages.

In principle it involves a rotor with drooping arms that allows a combination thrust and guide bearing to be placed under the rotor hub and close to the plane of the rotor rim. No upper guide bearing is required with this construction, the machine is lighter, the complication of oil pumps and piping is eliminated, and the machine can be erected and dismantled with lower headroom.

The saving in weight is effected by the fact that the main supporting bracket is smaller in diameter than in the ordinary design, since it rests on the foundation and does not span the stator frame.

No oil circulation system is required because the bearing design makes it possible to immerse both thrust and guide bearings in the same oil bath, the oil being cooled by water flowing through cooling coils situated in the oil bath.

The conventional two-bearing machine has a long shaft which projects beyond the upper bracket to allow room for the thrust bearing and upper guide bearings, both of which are supported by the upper bracket. When dismantling a machine of this construction the rotor cannot first be disconnected from the shaft and removed, and both rotor and shaft have to be removed together and raised a sufficient height to clear the stator frame.

With the umbrella design, on the other hand, it is merely necessary to disconnect the rotor from the shaft and to raise it to clear the top of the stator frame. The thrust and guide

bearings are next removed, after which the shaft is lifted up until it clears the lower bracket.

This work can not only be done in less headroom, but is also a simpler process and can be more quickly executed than in the case of the conventional type of machine.

The combination thrust and guide bearing is an important feature of the umbrella type generator. The Michell principle, involving individual segmental shoes, is used in the guide as well as in the thrust bearing. The guide bearing is located above the thrust bearing and makes contact with the outer periphery of the thrust bearing runner.

This arrangement brings the centre-line of the guide bearing and the plane of the centre of gravity of the rotor close together and renders an upper guide bearing unnecessary.

The thrust bearing is supported on the lower bracket and carries the entire weight of the revolving parts plus the hydraulic thrust due to the turbine runner.

In the case of the Tongland machines this amounts to a normal thrust of 110 tons and 140 tons at runaway speed.

Each of the three main alternators at Tongland is designed for a 3-phase continuous maximum rating of 13,750 kVA., 0.8 power factor, 11,000 volts, 50 cycles, at 214 r.p.m., with temperature rises not exceeding those specified in B.S.S. 226/1925. Each machine is also capable of supplying, for line charging purposes, approximately 50 per cent. of its kVA. rating at zero leading power factor with positive excitation at the sliprings.

To meet the requirements of the turbine the alternator rotor embodies a flywheel effect of 4.5×106 lbs./ft.^{2} (W.R.^{2}), and is designed for a runaway speed 95 per cent. above normal with a factor of safety not less than 3.5 based on the ultimate strength of the materials.

Stator.

The stator frame is made of fabricated steel and is divided into three sections securely bolted together by internal vertical flanges.

The lower face of the frame is bolted and dowelled to the generator support already described and shown in Fig. 8. Lateral adjustment by means of adjusting screws is provided to permit centreing of the stator with respect to the rotor before dowelling.

Fig. 15 shows a section of the stator frame in course of fabrication ; this particular photograph represents part of one of the frames for the Glenlee alternators, but the construction of the Tongland frames is on exactly the same lines, and the strength and rigidity of the design is plainly evident.

The stator core is built up of thin laminations of annealed soft iron containing a sufficient quantity of silicon to eliminate ageing and increase the resistance without causing brittleness.

The laminations are stamped out in segments which are secured to the frame by dovetail keys which fit into slots stamped on the outer periphery of the core plates. Open type slots to receive the winding are stamped out on the inner periphery.

The laminations are built up with short packets of graded length to give equal temperature distribution throughout the core. Each lamination is insulated from its neighbour with a heat-resisting material so as to minimise eddy currents and the

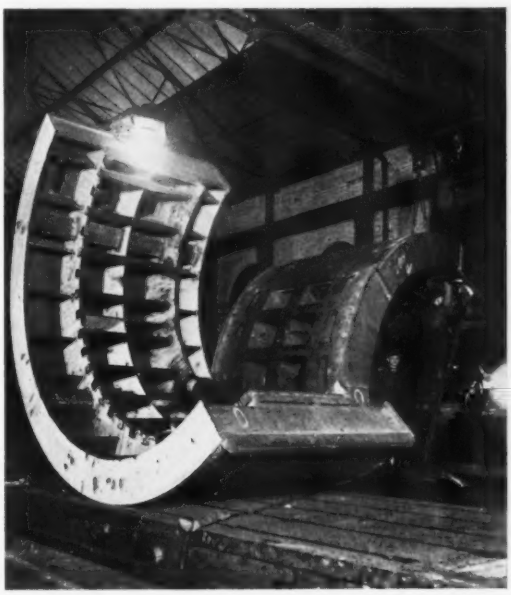

Fig. 15.—Stator Frame in course of fabrication.

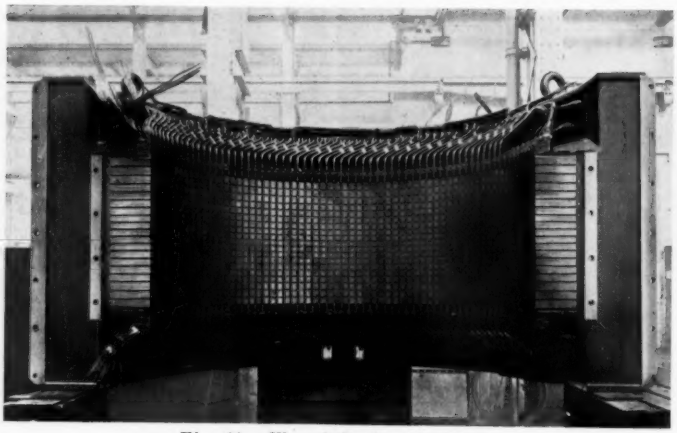

Fig. 16.—Wound Section of Stator.

whole core was tested magnetically before winding to ensure that the iron had suffered no damage in the course of manufacture.

Spacers are welded to the outside plates of each packet, the intervening spaces acting as ventilating ducts for cooling the core. Suitable fingers are provided on the end plates at the top and bottom of the core to prevent vibration of the teeth. The core was pressed at frequent intervals during manufacture and was finally clamped by the top end plate segments which are keyed to the stator frame to prevent any axial movement of the core plates.

The stator winding is of the two-layer or basket type, all coils being identical and thus interchangeable, each coil consisting of several conductors suitably proportioned to minimise losses on-load due to eddy currents.

The insulation is Class " B " quality throughout. The straight slot portion of the coils, which extends some inches beyond the end of the core, is insulated with mica tape and pressed before application of the main wrapping.

The main insulation of the part of the coils forming the overhang is linen-backed mica tape, sealed with special non-hygroscopic insulating varnish. There is a final tape covering for mechanical protection of this part of the coil.

The coils are held in position in open slots, lined with leatheroid, by impregnated hard-wood wedges driven into notches formed near the top of the slots. These wedges are shaped so as to give easy entry for the air to radial ducts. The end winding is supported against forces arising on short-circuit by lashing it back to mica-insulated coil support rings, secured to the frame by brackets at frequent intervals. Wedges were also used between coils for this purpose.

Fig. 16 shows a section of a stator with the winding in position ; this, again, actually represents one of the Glenlee alternators, but the Tongland design and construction is precisely similar.

Shaft and Thrust Bearing.

The generator shaft is a short, single-piece forging provided with a massive flange at the upper end. The horizontal underside of the flange carries the running member of the thrust bearing and the vertical cylindrical surface of this member acts as the running element of the single guide bearing.

Fig. 17.—Thrust and Guide Bearing for Tongland Alternator.

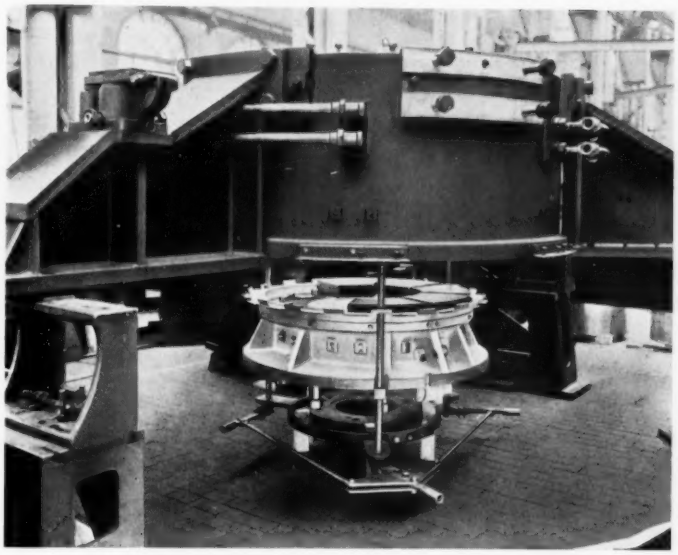

Fig. 18.—Showing method of removing Thrust Bearing Assembly from lower bracket.

The stationary members, both of the thrust and the guide bearing, are made up of a number of tilting pads on the Michell principle.

Fig. 17 illustrates the disposition of these adjustable pads in the fabricated steel oil-bath which forms the centre portion of the fabricated steel lower bracket. The concentration of all the machine bearings in the oil-bath completely eliminates, as already mentioned, any oil circulating system.

One of the advantages of the umbrella type of machine is that the thrust bearing can be removed downwards for inspection without disturbing any other part of the unit, and Fig. 18 shows the thrust bearing assembly being removed from the lower bracket. During this operation the weight of the revolving parts can be supported by applying oil at a pressure of 1,700 lbs. per square inch to the six brake cylinders, and then, if necessary, by using follow-up jack screws, one of which is provided alongside each brake cylinder.

The brake cylinders can be seen in Fig. 18 mounted on the lower bracket arms ; for ordinary braking purposes the cylinders are supplied with compressed air at about 40 or 50 lbs. per square inch. The brakes are designed to bring the rotor to rest from full speed in about 5 minutes.

The brake shoes are lined with heavy duty Ferodo asbestos and bear against a renewable brake track secured to the underside of the rotor.

It will be noted that the massive lower bracket and oil-bath are of fabricated construction.

Rotor.

The rotor rim consists of segmental steel laminations stacked 1/4 lap and clamped between steel end plates by means of fitted bolts in reamered holes, so that the rim forms a self-supporting chain and does not exert any centrifugal pull on the cast steel rotor centre, even at the runaway speed of the turbine,

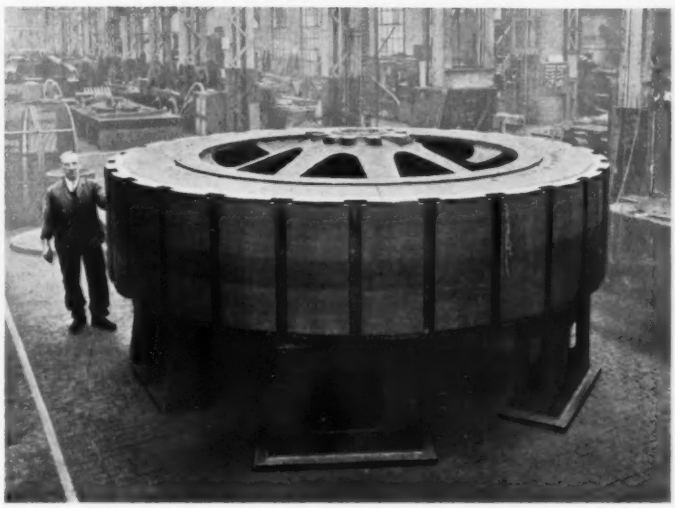

Fig. 19.—Tongland Alternator Rotor Body.

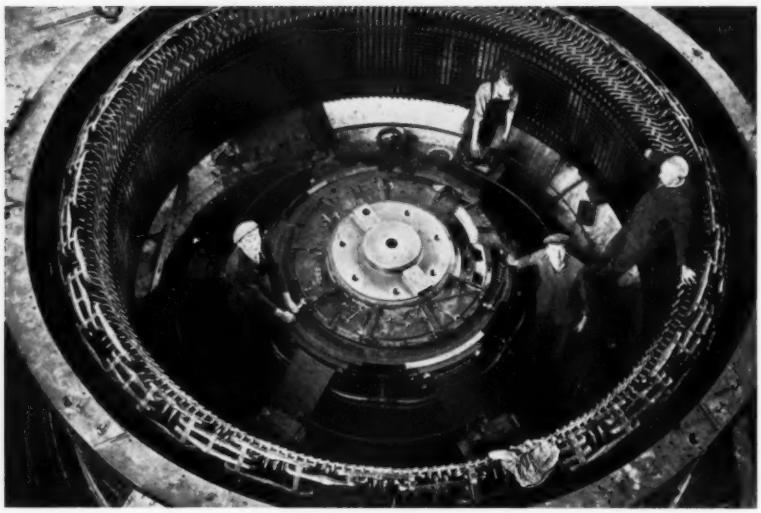

Fig. 20.—Tongland Alternator Stator in course of erection ready to receive Rotor.

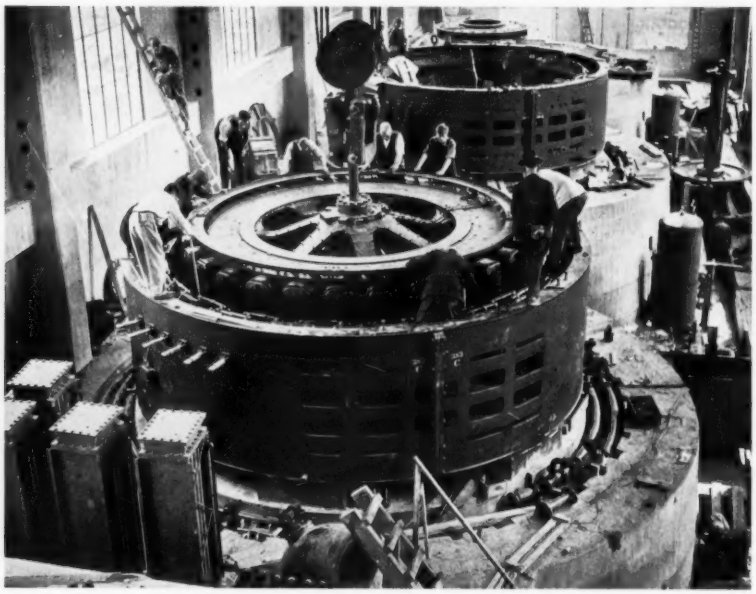

Fig. 21.—Rotor being lowered into position.

which, as mentioned above, is 95 per cent. above the normal 50-cycle synchronous speed.

One of the rotor bodies is shown in Fig. 19.

The rotor is held to the shaft by a force fit on the section of the shaft projecting up within the rotor hub, and also by vertical bolts through the horizontal flange of the spider screwed into the flange of the shaft.

The torque is transmitted, not by means of the bolts, but by a transverse key.

The poles are of laminated steel, riveted between cast steel end plates.

The pole plates and end plates are provided with dovetails which fit, with the aid of taper keys, into specially shaped dovetail slots, provided in the periphery of the rotor rim. The poles and their coils can, therefore, be removed without disturbing any part of the machine, other than the exciter support bracket by sliding them along the rim parallel to the shaft.

The field coils are formed of copper strip wound on edge and are submitted during manufacture to a pressure in excess of the centrifugal force on the outer turn at overspeed.

Fan blades are fitted at both ends of the rotor adjacent to the field coils.

Ventilation.

The alternators are self-ventilating by means of rotor fans, and they operate on the closed-circuit principle, the hot air being passed through six water-cooled air coolers spaced round the periphery of the stator frame before re-entering the fans. The exciters are also totally enclosed and forced ventilated.

The air circulates within a sheet metal casing which gives the machine a very neat appearance, as will be appreciated from the frontispiece and Fig. 5 in the first issue of this article. (Vol. VIII, No. 1.)

The air coolers consist of a number of tubes, the outer surfaces of which are covered with fins for rapid transference of heat. The tube plates are covered by cast iron water headers, having inlet and outlet connections and partitions for distributing the water flow to best advantage. The cooling water is supplied direct from the pipeline and passes through Duplex strainers to a ring main round the top of the generator pedestal and thence to the coolers.

The strainers are shown in Fig. 5 on the right of the generator pedestal, and the ring mains in course of assembly can be seen in Fig. 21, in their duct on the top of the pedestal.

It may here be explained that the closed-circuit system was adopted firstly to avoid the large amount of hot air which the three machines, on open circuit ventilation, would discharge into the engine room, with consequent discomfort to the operating staff ; secondly, to make the station as silent as possible ; and thirdly, to minimise the amount of moisture which might, on the open circuit principle, be passed through the alternators during the wet and humid seasons of the year.

In this latter connection, electric heaters of the tubular type have been fitted inside the casings to keep the temperature of the alternators above the dew point when the sets are standing idle during the wet season. These are controlled by thermostat and contactor in such a manner that they are switched on and off according to the temperature.

A feature which contributes greatly to the convenient and efficient operation of the plant is the indicator panel which is provided for each generator and mounted at the foot of the pedestal as shown in Fig. 5.

Upon this panel are neatly assembled the lubricating oil pressure and spiral casing water pressure gauges, the draft tube vacuum gauge, the bearing temperature indicators, the ventilating air temperature indicator, the lubricating oil pump contactor, the generator heater contactor, alarm relay, telephone, etc.

The generators were assembled at Stafford Works before despatch and running tests were carried out, including overspeed tests, and this procedure was followed on the five machines for Tongland and Glenlee, comprising the first stage of the Galloway development and on the six machines for the second stage, totalling eleven machines in all.

On account of the vertical shaft design and the exceptional size of the machines, special arrangements had to be made for assembly and accommodation on the test bed, but the whole of the

tests passed off satisfactorily and with great smoothness.

This was particularly marked in the case of the overspeed tests, which at first created great attention, but finally, through lack of incident, came to be regarded as ordinary routine tests on the later machines.

Every machine was run on the test bed at 95 per cent. overspeed for five minutes and, despite the fact that on account of the restrictions of the test assembly, the temporary lower guide bearing had to be closer to the alternator guide bearing than on site, there was an entire absence of vibration.

Figs. 20 and 21 show the Tongland alternators being erected on site. The former gives a view of the stator shaft and lower bracket ready to receive the rotor. The latter shows the rotor being lowered into position, and in the left foreground can be seen four of the air coolers awaiting erection.

Both the Tongland and the Glenlee units were put into service early last year with the very minimum of preliminary adjustment and have run practically continuously and very satisfactorily ever since, a meritorious achievement for plant characterised by such novelty in design.

Note.—The aerial view of Tongland Power Station reproduced in our February, 1936, issue is the copyright of the Galloway Water Power Company and was published by the courtesy of that Company.

(This article will be continued in the next issue.)

Protection of Motors.

With Special Reference to the "English Electric" Burn-out Protector.

By L. ROBERTS, M.I.E.E., Manager Industrial Sales and Engineering Department, and R. D. BALL, A.M.I.E.E.

(Reprinted from "The Electrical Times," 13th February, 1936.)

The usual present-day methods of safeguarding motors—low voltage and overload coils fitted on the starter—provide satisfactorily against failure to start, stalled condition, and continuous heavy overloads. They do not, however, protect against a number of other conditions. Overheating of a motor may result from failure of the ventilation system, due to ducts and windings becoming choked; frequently repeated overloads, cumulative in their temperature effect but individually not so severe as to operate the customary protective devices; high ambient air temperature, such that when normal motor temperature rise is added conditions dangerous to the windings result; and abnormal starting, e.g., if the starting-duty cycle is accelerated for any reason, it may result in overheating of the motor. All these causes of failure are linked with the actual temperature of the motor windings. Protection against them therefore requires a temperature actuated device fitted on the motor itself.

Causes of Overheating.

Perhaps the most frequent cause of motor windings burning out is due to blocking of the ventilation ducts. Under such conditions even normal full load currents can produce dangerous temperatures, and since the motor is not overloaded the overload relay on the starter does not function. This trouble is, perhaps, more common with modern machines than with those built, say, a quarter of a century ago. A corollary of the development of scientific ventilation of motors has been economy in the amounts of active iron and copper used for a given horse power. Consequently, if anything intervenes to reduce or negative ventilation the natural heat dissipation capacity of the motor is inadequate and overheating results. This does not constitute a

Fig. 1. "Closvent" Motor with Fan Cowl Removed. Showing how the ventilation paths of motors in certain textile factories eventually become choked.

criticism of modern design, but emphasises that ventilation is an inherent factor of motor design and care must be taken in operation that the ventilation is not impaired. Figs. 1 and 2 illustrate what may happen to motors when they get into service. It is all very well to say that it is part of the factory electrician's duty to see that motors are kept clean and free from clogging, but unless a very elaborate maintenance service is in force it is not at all easy to ensure that burn-out trouble will not develop from time to time. A safeguard, however, can be provided if a device that protects against overheating is fitted on each machine. It was considerations as above that led the authors to develop the device described below.

The burn-out protector is eminently suitable for protection against single phasing. If any three-phase motor remains running on single phase, then inherently with the same driven load the input current to the motor increases considerably, and therefore the machine would tend to heat up to an excessive temperature. The Company's burn-out protector has been developed to safeguard the motor should such conditions arise.

The Burn-out Protector.

After careful consideration, it was decided that if a burn-out protector could be made which would be suitable for low-tension machines (and machines with low-voltage relays arranged for low-tension supplies) up to about 400 h.p., such a device would cover a large percentage of those machines which are usually placed in positions where this extra protection is necessary. As it was desirable to have only one size of burn-out protector for the range of, say, 1 h.p. to 400 h.p., the protector had necessarily to be of small dimensions to be accommodated in the small machines; but also it had to have sufficiently large capacity for the larger machines. After many experiments the most convenient shape was found to be rectangular, and the dimensions were reduced to $2\frac{3}{4}$ in. by $1\frac{1}{4}$ in. by 1 in. approximately.

The burn-out protector thus evolved consists of a special bi-metal strip and the necessary contacts, with tungsten-tips, enclosed in a bakelite case. The device can easily be fixed to the stator core, in some suitable position, by means of the metal plate (which seals the protector)—see Fig. 3. The two leads from the protector are then connected in series with the coil circuit of the low-voltage relay. With this device fitted, if the temperature of the stator core rises to approximately 190° F. due to any cause, then the burn-out protector opens the low-voltage circuit, thus stopping the motor, which cannot be re-started

Fig. 2. Stator of Pipe Ventilated Squirrel Cage Motor, after several months' service in an oil-cake mill, showing how the windings become choked due to foreign matter in the external air.

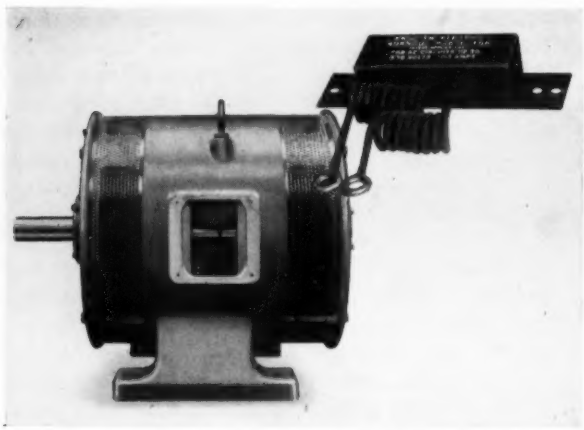

Fig. 3. English Electric "Burn-out Protector."
The top right-hand view shows the Protector separately, and, on the left, the manner in which it is fitted to the stator core behind the terminal box.

until it has cooled down. The operating characteristics of the burn-out protector are clearly shown in Charts 1 to 4. It was considered necessary that the burn-out protectors should be calibrated and sealed before leaving the works, so that the setting could not be tampered with, and also to exclude dirt when in service.

Trip Temperature, 190° F.

From research carried out by Raynor, Crompton and Siemens (E.S.C. Report No. 22, dated 1905), it was ascertained that if impregnated cotton is subjected to a temperature of approximately 100° C. (212° F.) for prolonged periods, deterioration of the insulation is very rapid. Taking into account the above report, and also that B.S.S. 168, dated 1926, allows 50° C. rise above an ambient air temperature of 40° C., that is, a total temperature of 90° C. or 194° F., it is obvious that if the burn-out protector is set to trip at approximately 190° F., then it will safeguard against this deterioration, and therefore eliminate burn-outs to a very great extent. The burn-out protectors have, therefore, been calibrated for approximately 190° F. tripping temperature, and it will be appreciated that wherever a motor is situated, and whatever the climate, it will be protected against failure of ventilation, frequently repeated over-loads, variable room temperature, or abnormal starting. (Most industrial machines have Class A. insulation).

General Comment.

It should be noted that this class of device cannot protect the motor against sudden over-loads, such as short-circuit or earth fault. It is quite possible for a motor to have such a heavy load that it would be stalled, and before the temperature of the stator iron could rise to a sufficient value to trip the device the machine would be burned out. For such conditions only a quick-acting breaker or a reliable high-rupturing-capacity cartridge fuse would be a safeguard, as it

Charts showing how the "Burn-out Protector," when fitted to motors, protects against various contingencies which may arise, conditions that normal protection fitted on control gear would not deal with.

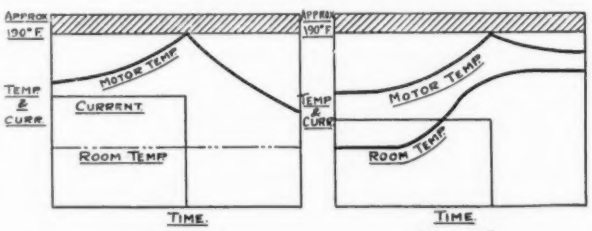

CHART 1.

Shows the effect of reduction in ventilation of Motor due to dirt, fluff, etc., the Motor being shut down by "Burn-out Protector" when dangerous Motor Temperatures are reached.

CHART 2.

Shows the effect of the ambient air temperature rising, and shows how the "Burn-out Protector" stops the Motor when dangerous Motor Temperatures are reached.

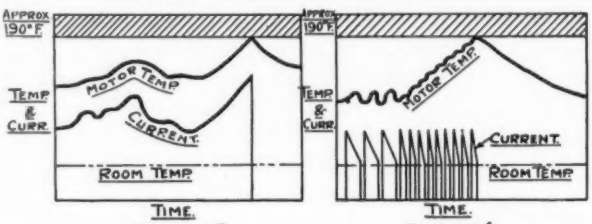

CHART 3.

Shows the effect of intermittent and recurring overloads and how the "Burn-out Protector" shuts down the Motor when dangerous Motor Temperatures are reached.

CHART 4.

Shows what happens when the number of starts is excessive and how the "Burn-out Protector" shuts down the Motor when dangerous Temperatures are reached.

should be appreciated that a motor of reasonable size, if stalled, can be burned out in little over a minute. The question might be asked, what is the ideal protection for motors? In the authors' opinion this comprises fuses or magnetic overload relays and low-voltage protection on the starter, with a burn-out protector on the motor. The burn-out protector allows the motor to give its maximum output and considerably lessens the possibility of damage to the insulation. Overload relays of the thermal type, incorporated in the starter, are usually based on current capacity and rarely simulate the actual thermal characteristics of the machine; also the starter may not be in the same room as the motor, and in consequence may be in different ambient air conditions.

The "English Electric" System of Electrical Precipitation—Some Typical Installations.

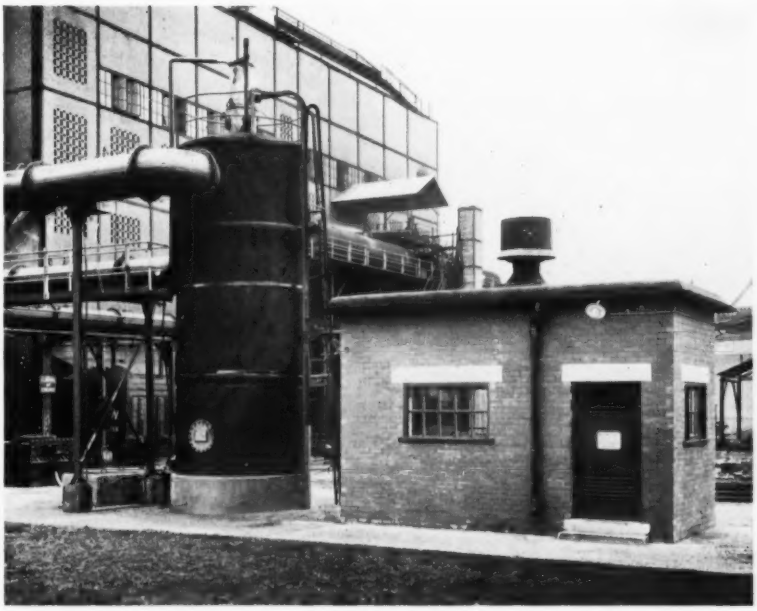

Fig. 1.—Electro-Detarring Installation at the Partington Gas Works, Manchester.

The development of the "English Electric" direct generation system for providing direct current at high voltage for the cleaning of industrial gases was fully described in the June, 1934, issue of this Journal. The number of equipments put into service since that date is evidence of the success of the system.

The purpose of this article is to describe in more detail typical plants which have their own unique features. The main difference in the electrical plant lies in the arrangement of the high-tension D.C. generating equipment to meet the varied conditions of motive power available and also to provide flexibility in

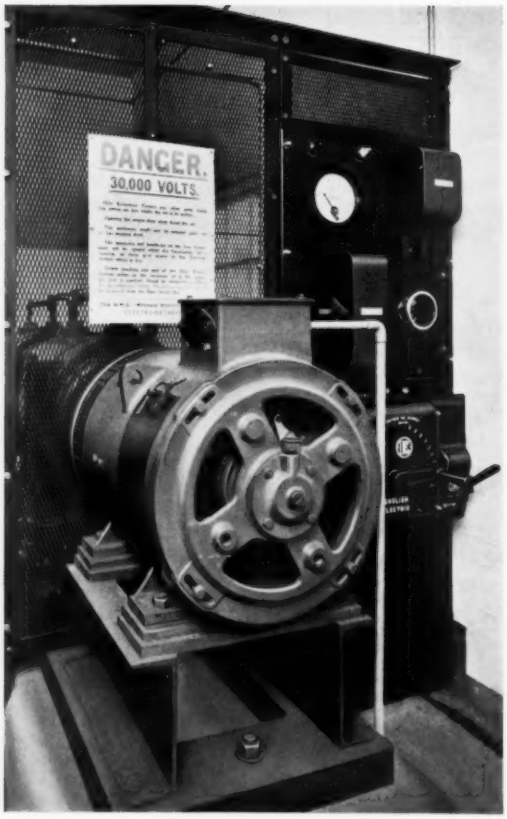

Fig. 2.—Interior of Generator House of Installation shown in Fig. 1.

the plants which consist of two or more treating vessels.

A typical arrangement of a single-treater equipment is illustrated in Figure 1, which shows a treating vessel capable of dealing with nine to ten million cubic feet of gas per day with an extraction efficiency of 99.8 per cent.

The high-tension D.C. generating set is accommodated in the building seen on the right of Fig. 1, and consists of two standard " English Electric " high-tension D.C. generators mechanically coupled in tandem to a 440-volt, 8.5 h.p. D.C. driving motor, the continuous rated output of the set being 150 mA. at 30 kV. The interior of the generator house is shown in Fig. 2, which gives a clear indication of the simplicity of the complete equipment. It will be noted that the control gear and the motor generator set are readily accessible and the equipment is such as to be easily understood by the works' electrician.

The starting up is controlled by a standard type faceplate starter, the variation of treater current being obtained by changing the speed of the driving motor by means of a shunt-field regulator. A milliammeter and overload coil are connected between the positive terminal of the motor generator set and earth to register the current to the treater and to protect the motor generator set in the event of a fault in the treating vessel, such as a broken wire, which would cause a " dead " short-circuit. The overload relay is fitted with a dashpot time lag to prevent a shut down of the set on the occasion of a temporary flashover in the treater tubes due to tar bridging.

In the event of a shut down of the set due to a broken wire, visual and aural signals are provided at any desired point to give indication that the set has tripped out.

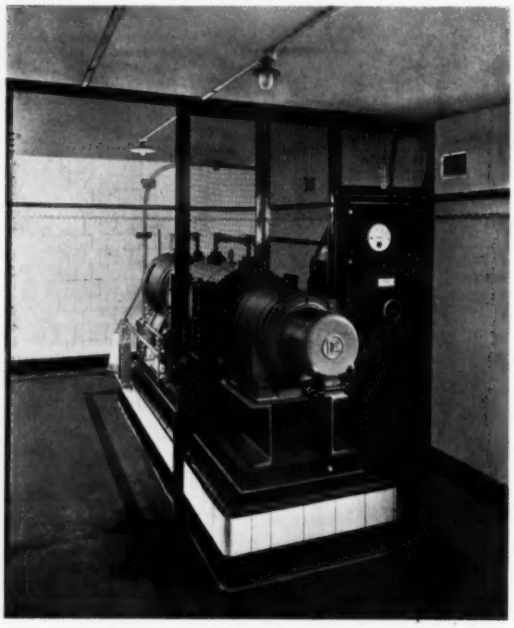

Fig. 3.—High-tension D.C. Generator House at the works of Thorncliffe Coal Distillation, Ltd.

Fig. 3 illustrates a similar single-unit equipment, but in this case the available supply is three-phase A.C. The driving motor is of the slipring induction type, speed control being obtained by the use of a rotor resistance regulator. The control gear for the motor is of the contactor type, which enables starting and stopping to be effected by the simple operation of a small control switch. The metering and overload protection of the motor generator set is identical on all equipments, the overload relay contacts shutting off the main power supply.

To comply with Home Office requirements, a hand-operated earthing switch is fitted, which is so interlocked with the screen door that the set is shut down and effectively earthed before access to the motor generator set is possible. This is a standard component on all " English Electric " equipments.

In certain cases at medium-sized gas works a constant supply of electrical power is not available, and a case in point is illustrated in Fig. 4, where the prime mover supply is low-pressure steam. The set consists of an enclosed-type single-cylinder Sisson engine with a maximum output of 5 h.p. at 850/1,000 r.p.m., direct-coupled to two " English Electric " high-tension generators which supply negative high-tension at 30 kV. to the treater. The engine is equipped with a patented Sisson automatic expansion shaft governor, which not only controls the speed to very close limits, but results in great economy of steam consumption.

A variable speed hand wheel control operating on the governor is also provided whereby the speed of the engine, and hence the output of the generator set, may be regulated whilst the set is running. The engine is also equipped with a special electrically and mechanically operated steam stop valve, the function of which is to shut down the set in the event of sustained short-circuit in the system.

The Company has in hand further equipment,

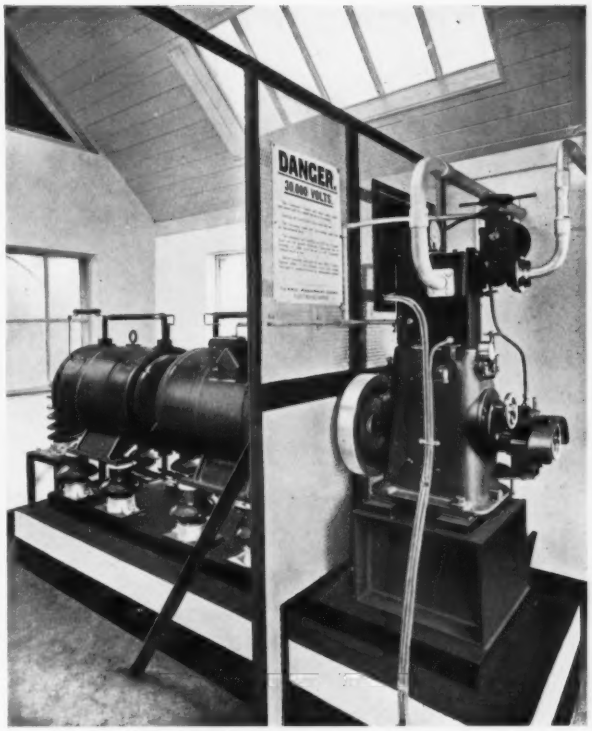

Fig. 4.—Steam Engine-driven High-tension Motor Generator Set at the Isle of Thanet Gas Company's Works, Margate.

the prime mover in this case being a high-speed geared turbine.

It is noteworthy that the " English Electric " direct generation system can be used in conjunction with practically any type of motive power whereas if transformer and rectifier equipments had been installed, a steam engine-driven alternator set would have been necessary.

In certain cases it is found necessary to install two treating vessels which can be supplied from one motor generator set. To facilitate the working of the plant and to provide flexibility of operation, high-tension isolating switchgear is provided to enable individual treaters to be inspected and overhauled without shut down of the complete system.

Fig. 5 illustrates a plant of this nature, where two treaters are supplied from one 30 kV. 150 mA. high-tension D.C. set consisting of two

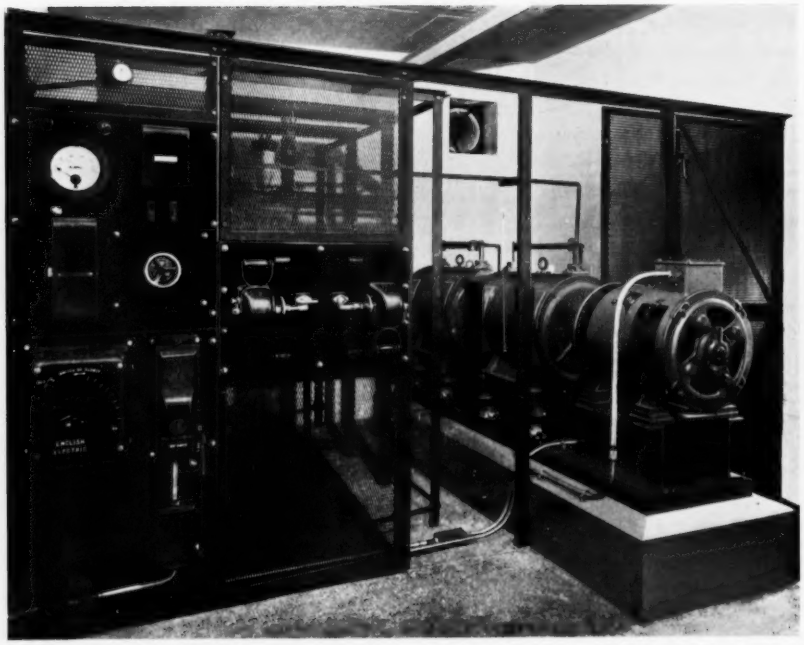

Fig. 5.—High-tension Motor Generator Set and Switchgear as supplied to the Edinburgh Corporation Gas Dept.

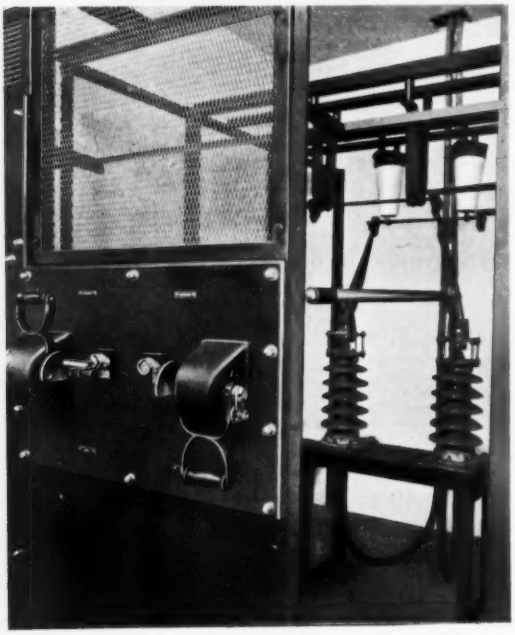

Fig. 6.—The High-tension Switchgear of the installation shown in Fig. 5.

standard high-tension generators and a 440-volt D.C. driving motor. The switchgear is remote operated by the mechanism on the central front panel, and is so interlocked that the switch must be in the earthed position before the handholes on the treater vessel can be opened.

A more detailed view of this switchgear is illustrated by Fig. 6, from which the simplicity, neat and compact nature of this equipment will be noted. This arrangement is admirably suited to cases where the capacity of the plant does not warrant the installation of twin motor generator sets, but under certain circumstances, where larger treating vessels are required, it is an advantage to install twin sets which are capable of feeding either treating vessel. An example of such an arrangement is shown in Fig. 7. It will be appreciated that for a comparatively large installation of this nature, such an arrangement produces an extremely flexible equipment.

In this case the available power supply is three-phase A.C., and the use of contactor type

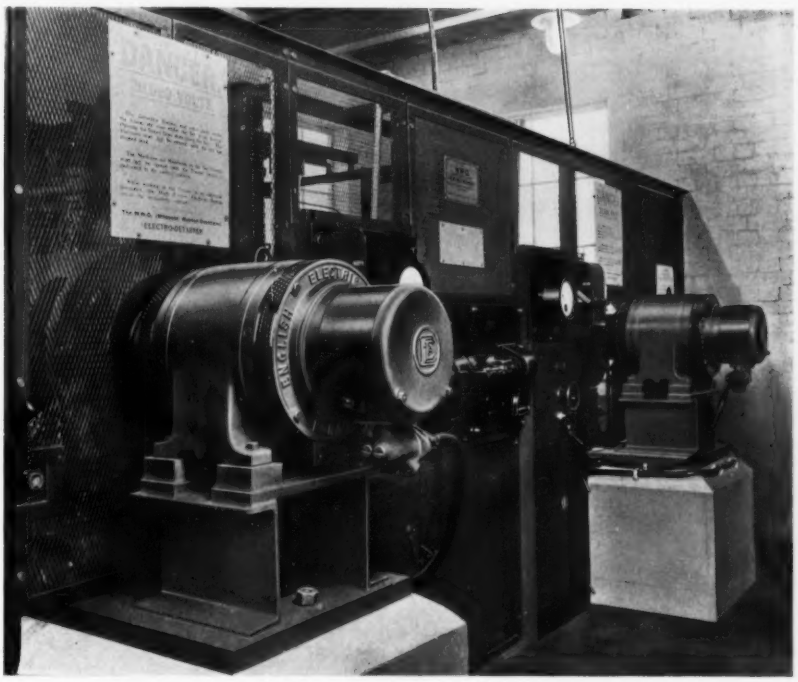

Fig. 7.—Twin High-tension Motor Generator Sets and Switchgear at the Coke Oven Plant of Messrs. Guest Keen Baldwins, Iron & Steel Co., Ltd., Cardiff.

control gear gives an exceptionally neat arrangement to the equipment.

The examples illustrated are only typical of the varied arrangements which can be provided by the use of the "English Electric" direct current system, and practically any plant requiring high-tension D.C. for electrical precipitation can be equipped with a simple and compact unit consisting of combinations of any of the arrangements illustrated in this article.

The gas treaters used in the installations described have been designed and manufactured by the Whessoe Foundry and Engineering Co., Ltd., Darlington.

New Steam Generating Plant for Turbine Testing at Rugby Works.

In recent years there has been a growing movement towards higher steam pressures and temperatures both in central generating stations and in stations supplying industrial plants. This has been rendered possible by modern advances in the knowledge of metallurgy which has swept away many of the limitations which formerly existed in the application of high pressures and temperatures.

In order that turbines designed for these conditions can be properly tested at the works, and also to allow of further experimental research

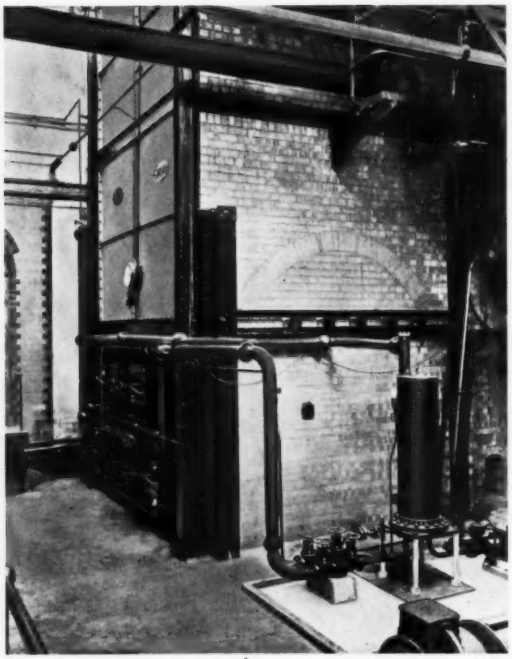

Fig. 1.—General view of High Pressure Boiler, showing Firing Front and Fuel-oil Heater.

in the problems connected with such high pressures and temperatures, the Company has recently augmented its Rugby Works' boiler plant by the addition of a new unit. This unit, which has just been put into operation, will enable steam turbines to be tested up to a pressure of 485 lbs./sq. in., and with steam at a total temperature of 850 degs. F.

The boiler is of a size such that turbines can be tested up to loads of about 4,000 kW. at the maximum pressure and temperature, the actual load obtained depending upon the conditions of the test.

The boiler is of the water-tube three-drum type manufactured and installed by the Stirling Boiler Company ; it has a normal evaporative capacity of 22,000 lbs. of steam per hour with a maximum steaming rate of 35,000 lbs. per hour for one hour.

In considering the type and lay-out of plant, it will be readily understood that questions of flexibility in operation and rapidity in starting up have been given priority over such considerations as thermal efficiency or operating economy. Continuous operation over long periods is not required since the nature of the duty demands only intermittent working and provision has to be made for laying up the plant during the periods between tests, in such a way that deterioration will not take place.

Oil firing has been selected as offering a convenient and quick means of starting up and as giving the necessary flexibility in control of evaporation demanded by the fluctuating requirements of factory tests.

The oil-storage tank is situated alongside a standard gauge rail siding at a level such that oil from the tank wagons may be run into the storage tank by gravity. A motor-driven pump drawing from this tank delivers oil to the burners through a heater and suitable filters. Two auxiliary pressure-jet burners provide the necessary heat for starting up from cold and as soon as a suitable pressure of steam is raised in the boiler the main steam atomising burners are brought into use.

The plant is designed and installed with its own auxiliary equipment as an entirely separate unit independent of the existing Works' low-pressure boiler plant, and is used solely for testing purposes.

The feed system comprises a main motor-driven centrifugal pump with a Weir reciprocating steam-operated pump as a stand-by. These pumps draw water from a 2,000-gallon feed storage tank and discharge into the boiler through a Hopkinson " Duo " feed water level regulator, which operates on a differential thermal principle.

A permanent steam line is run from the boiler to a stop valve situated in the test house from which temporary lines are run to the test beds as required, and in order to provide for the multiplicity of steam conditions, pressure and temperature regulating apparatus is installed in the permanent steam line to the test house. For the control of steam pressure a Hagan automatic pressure regulator, manufactured by Messrs. James Gordon & Co., is used ; this takes the form of a butterfly reducing valve controlled by a steam pressure connection from the reduced

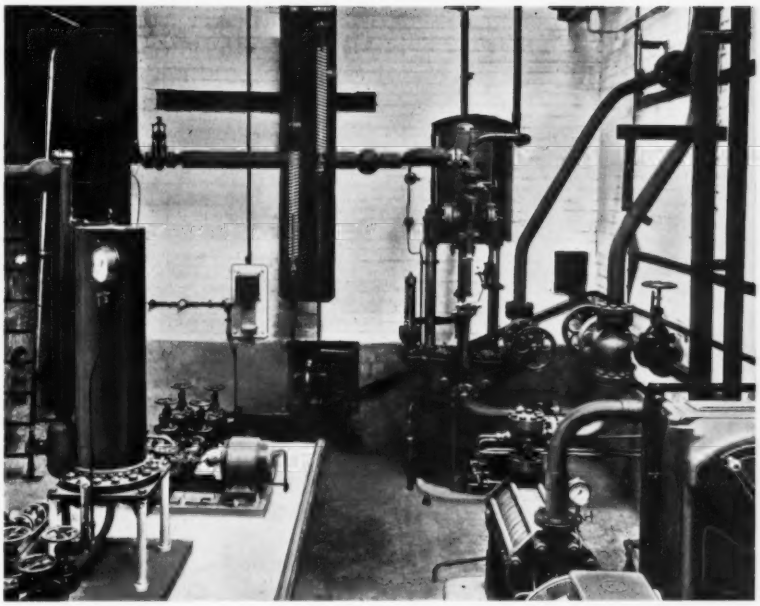

Fig. 2.—Auxiliary Plant for High Pressure Boiler, showing Feed Pumps and Fuel-oil Pump.

pressure line, working through a water-operated relay taking its supply from the town water main. Steam temperature control is obtained by means of a water spray desuperheater fed through a hand-controlled regulating valve; water supply to the desuperheater is taken from the high-pressure boiler feed line at a point between the feed-pump and the feed-regulator.

In order to avoid the accumulation of water from the desuperheater in the steam line when the turbine stop valve is closed, the desuperheater regulating valve is mechanically coupled to the pressure regulator in such a manner that when the butterfly reducing valve closes, the desuperheater valve closes with it. Thus, when the flow of steam to the turbine is interrupted, it is ensured automatically that the water supply is cut off.

By these means it is possible with the new boiler plant to test turbines for designed steam conditions from the maximum rated pressure and temperature of the boiler, down to 150 lbs. per square inch at saturation temperature and retain steady control of both pressure and temperature throughout the tests.

For the testing of turbines designed for comparatively low pressures, protection is afforded against excessive pressure rise when the turbine is tripped out or the stop valve otherwise closed, by means of a relief valve, set to blow at 200 lbs. per square inch, which is permanently mounted on the steam main and communicates with it through a stop valve. This stop valve is locked in the open position for all tests below a pressure of 200 lbs. per square inch, and is closed for tests above this pressure. The principle of employing one fixed intermediate relief pressure of 200 lbs. per square inch was selected in preference to the alternative method of having a relief valve with a set of springs to be adjusted separately for each test pressure, as being more reliable by virtue of its simplicity and less liable to error in operation such as could quite conceivably occur by the selection of the wrong spring.

A permanent condensing plant with cooling pond and sprays provides vacuum for such turbines as are not tested in the Works with their own condensers. Forming part of the Works' condensing plant are calibrated condensate tanks

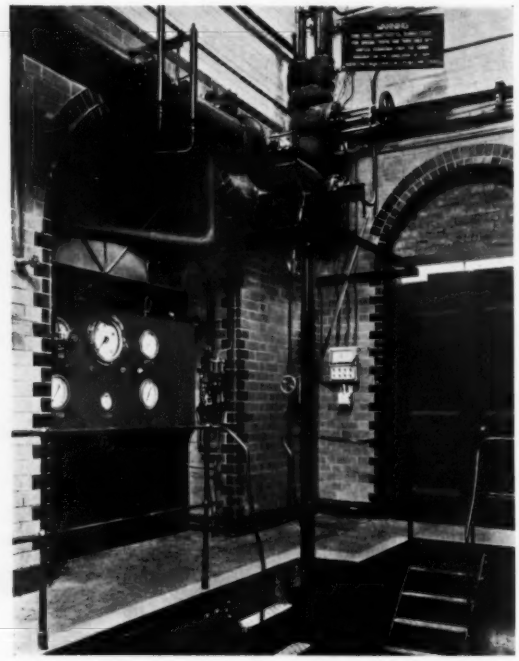

Fig. 3.—View showing Gauge Board, Pressure Regulator, Desuperheater and 200 lbs. Relief Valve.

for the purpose of taking customers' consumption tests and for special investigation on experimental turbine plant. A motor-driven pump takes the condensate from these tanks to the main feed storage tank.

Indicating instruments in connection with the steam generating plant show on a gauge panel facing the boiler front, steam pressures before and after the pressure regulator ; steam temperatures at boiler stop valve and at a point just prior to entering the test house ; steam flow in lbs. per hour, and water pressure to the relay gear operating the steam pressure regulator. The pressure regulator and desuperheater are grouped together with the main gauge panel opposite the boiler firing front in order that these auxiliaries may be under the constant supervision of the engineer in charge.

Telephonic communication by means of loud-speaking telephones is provided between the test house and boiler house, and, in addition, an electric signal lamp system is installed for emergency signalling in order to avoid the delay in telephoning when prompt action is necessary.

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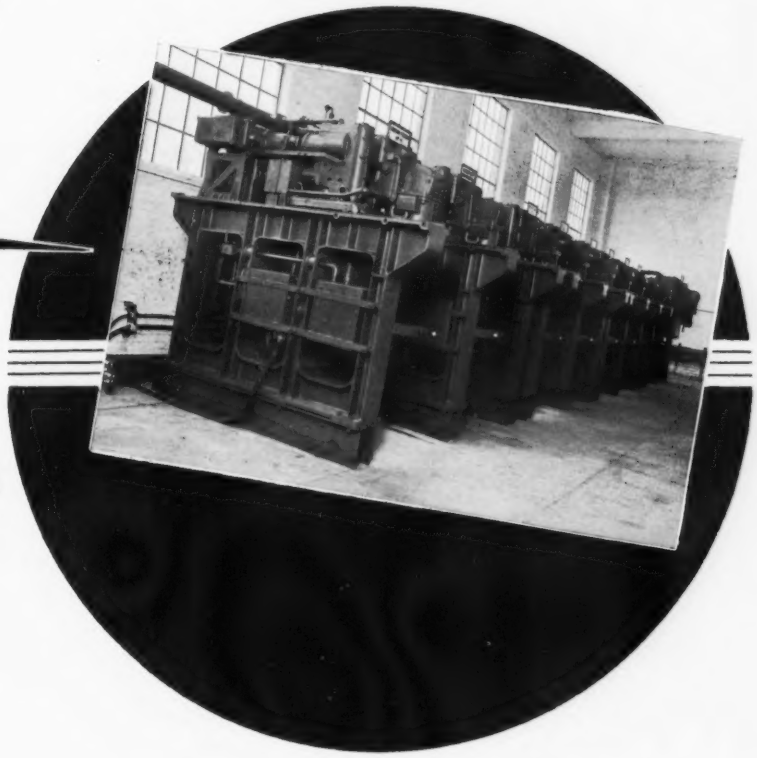

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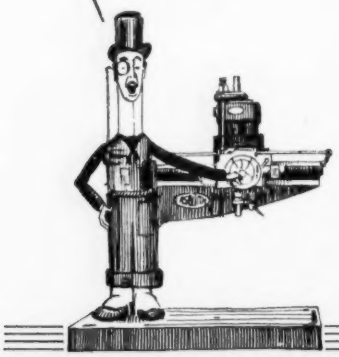

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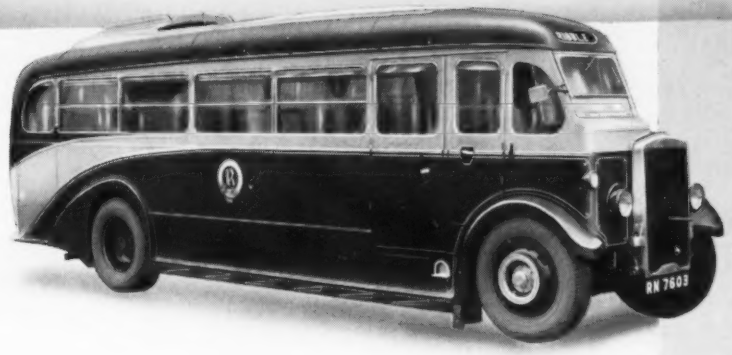
The upper illustration shows a long distance Coach seating 31 passengers, built for the South Yorkshire Motors Limited.
Nearside front entrance; offside front emergency exit; large parcel racks; luxury finish; all seats facing forward.



The lower illustration shows a long distance Coach seating 31 passengers, built for the Ribble Motor Services Limited.
Nearside front entrance; offside front emergency exit; single panel sliding roof; luggage lockers; parcel racks; thermostatically controlled heaters; luxury finish.

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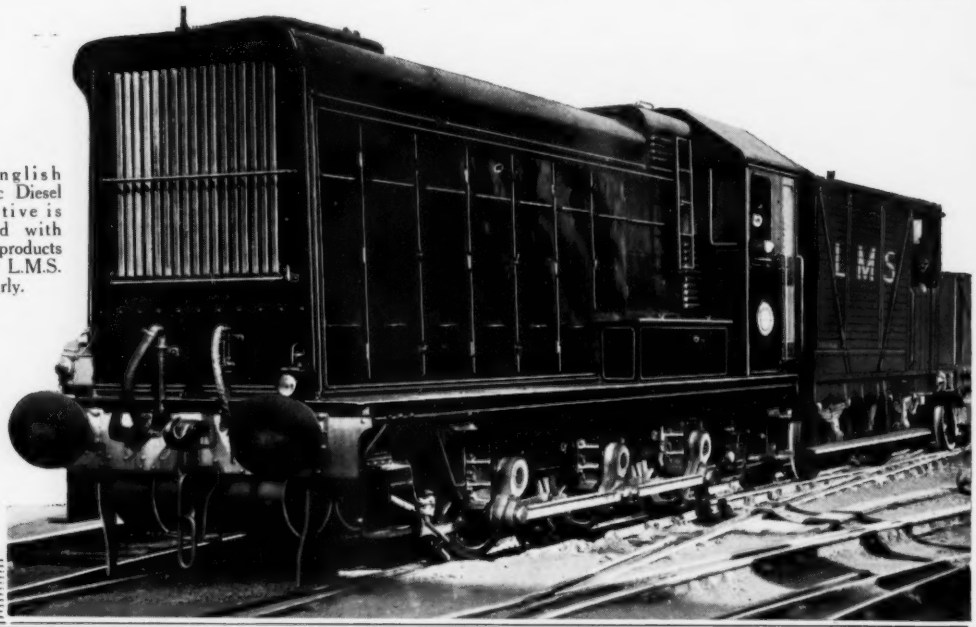

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